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EN 14651

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English version

Test method for metallic fibered concrete - Measuring the flexural tensile strength (limit of proportionality (LOP), residual)

Méthode d'essai du béton de fibres métalliques - Mesurage de la résistance à la traction par flexion (limite de proportionnalité (LOP), résistance résiduelle)

Prüfverfahren für Beton mit metallischen Fasern - Bestimmung der Biegezugfestigkeit (Proportionalitätsgrenze, residuelle Biegezugfestigkeit)

This European Standard was approved by CEN on 3 April 2005.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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Foreword

This document (EN 14651:2005) has been prepared by Technical Committee CEN/TC 229 "Precast concrete products", the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by December 2005, and conflicting national standards shall be withdrawn at the latest by December 2005.

This standard is one of a series concerned with testing metallic fibered concrete.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

1 Scope

This European Standard specifies a method of measuring the flexural tensile strength of metallic fibered concrete on moulded test specimen. The method provides for the determination of the limit of proportionality (*LOP*) and of a set of residual flexural tensile strength values.

This testing method is intended for metallic fibres no longer than 60 mm. The method can also be used for a combination of metallic fibres and, a combination of metallic fibres with other fibres.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 12350-1, *Testing fresh concrete − Part 1: Sampling*.

EN 12390-1, *Testing hardened concrete – Part 1: Shape, dimensions and other requirements for specimens and moulds*.

EN 12390-2, *Testing hardened concrete – Part 2: Making and curing specimens for strength tests*.

EN 12390-4, *Testing hardened concrete – Part 4: Compressive strength – Specification for testing machines*.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
crack mouth opening displacement
linear displacement measured by a transducer installed as specified in 7.1 and illustrated in Figure 4, on a prism subjected to a centre-point load F

3.2
deflection
linear displacement measured by a transducer installed as specified in 7.1 and illustrated in Figure 5, on a prism subjected to a centre-point load F

3.3
limit of proportionality
stress at the tip of the notch which is assumed to act in an uncracked mid-span section, with linear stress distribution, of a prism subjected to the centre-point load F_L defined in 8.2

3.4
residual flexural tensile strength
fictitious stress at the tip of the notch which is assumed to act in an uncracked mid-span section, with linear stress distribution, of a prism subjected to the centre-point load F_j corresponding to $CMOD_j$ where $CMOD_j > CMOD_{F_L}$ or to δ_j where $\delta_j > \delta_{F_L}$ (j = 1,2,3,4)

4   Symbols and abbreviated terms

4.1   Symbols

$CMOD_{F_L}$ $CMOD$ at LOP

$CMOD_j$ value of $CMOD$, j = 1, 2, 3 or 4

F load

F_j load value, j = 1, 2, 3 or 4

F_L load at LOP

L length of test specimen

M bending moment

M_j bending moment value, j = 1, 2, 3 or 4

M_L bending moment corresponding to the load at LOP

b width of test specimen

$f_{R,j}$ residual flexural tensile strength, j = 1, 2, 3 or 4

$f_{ct,L}^{f}$ LOP

h_{sp} distance between the tip of the notch and the top of the test specimen in the mid-span section

l length of span

x width of notch

y distance between bottom of test specimen and axis of displacement transducer

δ deflection

δ_{F_L} deflection at LOP

δ_j deflection value, j = 1, 2, 3 or 4

4.2   Abbreviations

$CMOD$ crack mouth opening displacement

LOP limit of proportionality

5   Principle

The tensile behaviour of metallic fibre concrete is evaluated in terms of residual flexural tensile strength values determined from the load-crack mouth opening displacement curve or load-deflection curve obtained by applying a centre-point load on a simply supported notched prism.

6   Apparatus

6.1   Saw with rotating carborundum or diamond blade with adjustable and fixable cutting depth and 90° direction of saw-cut to the specimens lengths for notching the test specimens.

6.2   Calliper, capable of reading the dimensions of test specimens to an accuracy of 0,1 mm.

6.3   Rule, capable of reading the dimensions of test specimens to an accuracy of 1 mm.

6.4   Testing machine meeting the machine class 1 requirements in EN 12390-4, capable of operating in a controlled manner i.e. producing a constant rate of displacement (*CMOD* or deflection), and with sufficient stiffness to avoid unstable zones in the load-*CMOD* curve or load-deflection curve.

6.5   Device for transmitting the load of the testing machine to the test specimen, made up of two supporting rollers and one loading roller (see Figure 1).
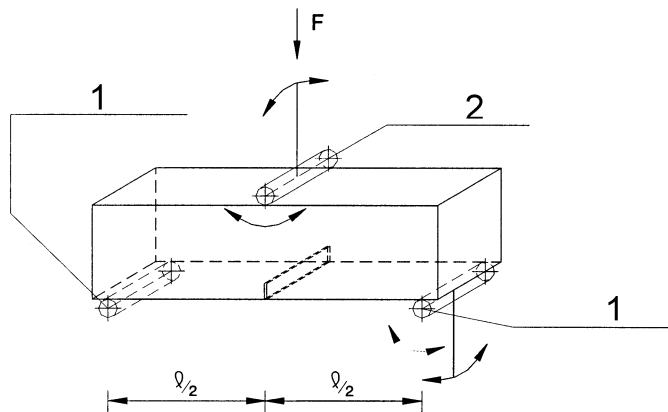
Key

1   Supporting roller
2   Loading roller

Figure 1 — Arrangement of loading of test specimen

All rollers shall be manufactured from steel and shall have a circular cross-section with a diameter of 30 mm ± 1 mm. They shall be at least 10 mm longer than the width of the test specimen. They shall have a clean and smooth surface.

Two rollers, including the upper one, shall be capable of rotating freely around their axis and of being inclined in a plane perpendicular to the longitudinal axis of the test specimen.

The distance between the centres of the supporting rollers (i.e. the span length) shall be equal to 500 mm. All rollers shall be adjusted to their correct position with all distances having an accuracy of ± 2,0 mm.

6.6   Load measuring device, capable of measuring loads to an accuracy of 0,1 kN.

6.7   Linear displacement transducer(s), capable of measuring displacements to an accuracy of 0,01 mm.

6.8   Device (frame or jig) for mounting displacement transducer(s), capable of being installed in a manner that ensures accurate determination of net mid-span deflections excluding any effects due to seating or twisting of the test specimen on its supports (only if deflection is measured instead of *CMOD*).

6.9   Data recording system coupled directly to electronic outputs of load and *CMOD* or deflection, with a recording rate not less than 5 Hz.

7   Test specimens

7.1   Shape and size of test specimens

The test specimens shall be prisms conforming to EN 12390-1 with a nominal size (width and depth) of 150 mm and a length L so that 550 mm $\leq L \leq$ 700 mm.

The specified shape and size of test specimens are suitable for concrete with maximum size of aggregate no larger than 32 mm and/or metallic fibres no longer than 60 mm.

7.2   Manufacture and curing of test specimens

The test specimens shall be cast and cured in compliance with EN 12350-1 and EN 12390-2 unless specified otherwise.

The procedure for filling the mould is indicated in Figure 2; the size of increment 1 should be twice that of increment 2. The mould shall be filled up to approximately 90 % of the height of the test specimen before compaction. The mould shall be topped up and levelled off while being compacted. Compaction shall be carried out by external vibration. In the case of self-compacting metallic fibre concrete, the mould shall be filled and levelled off without any compaction.
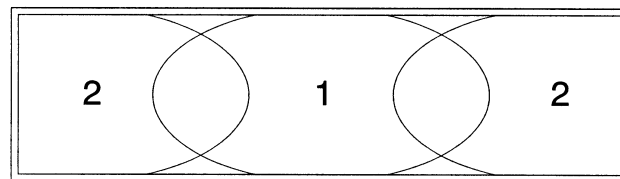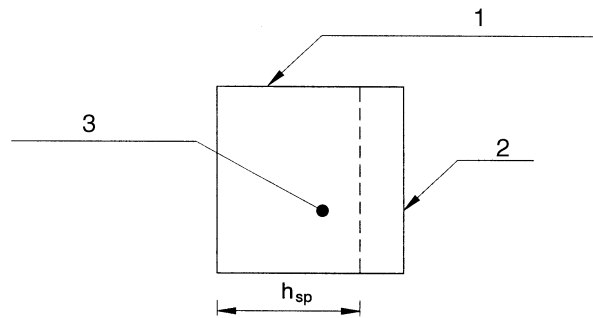

Key

1 and 2 order of filling

Figure 2 — Procedure for filling the mould

7.3   Notching of test specimens

Wet sawing shall be used to notch the test specimens. Specimens shall be rotated over 90° around their longitudinal axis and then sawn through the width of specimen at mid-span (see Figure 3).

Key

1   Top surface during casting
2   Notch
3   Cross-section of test specimen

Figure 3 — Position of the notch sawn into the test specimen before rotating

The width of the notch $\times$ shall be 5 mm or less, the distance h_{sp} shall be 125 mm ± 1 mm (see Figure 4).

The test specimens shall be cured according to EN 12390-2, unless specified otherwise, for a minimum of 3 days after sawing until no more than 3 h before testing (leaving sufficient time for preparation including any location devices for the transducer(s)). Testing shall normally be performed at 28 days.

8   Testing procedure

8.1   Preparation and positioning of test specimens

The average width of the specimen and distance between the tip of the notch and the top of the specimen in the mid-span section shall be determined from two measurements to the nearest 0,1 mm of width and distance in the notched part of the test specimen, using callipers.

When the crack (or notch) mouth opening displacement is measured, a displacement transducer shall be mounted along the longitudinal axis at the mid-width of the test specimen, such that the distance y between the bottom of the specimen and the line of measurement is 5 mm or less (see Figure 4).

Dimensions in millimetres

section A-A
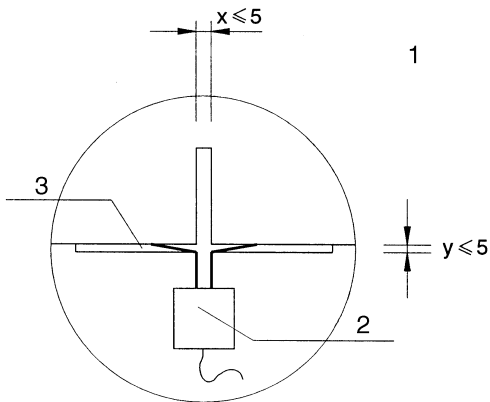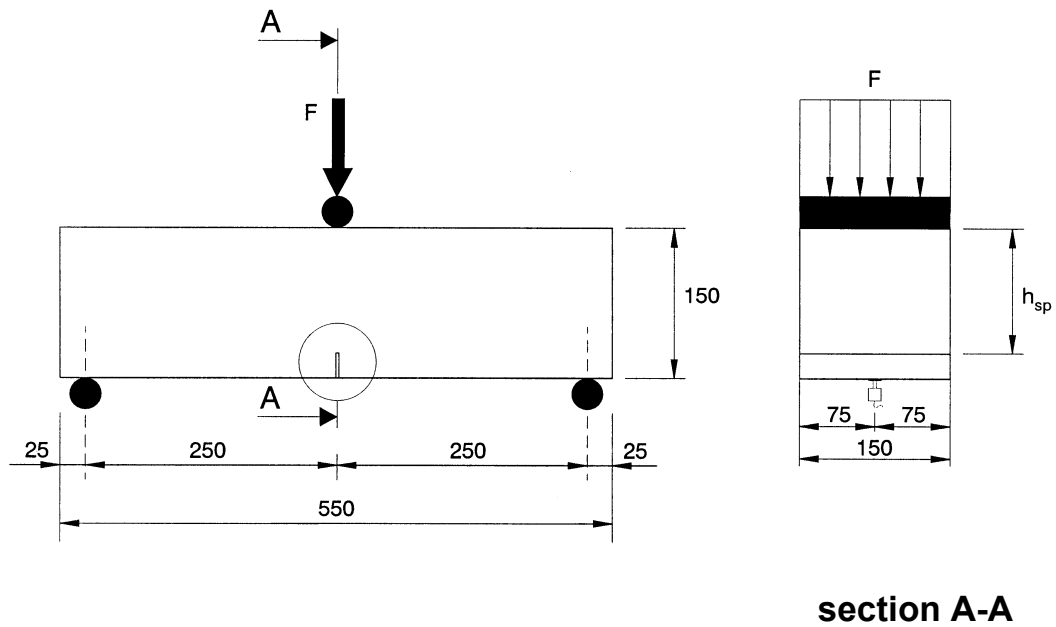
Key

1   Detail (notch)
2   Transducer (clip gauge)
3   Knife edge

Figure 4 — Typical arrangement for measuring CMOD

When the deflection is measured instead of the *CMOD*, a typical arrangement is as follows. A displacement transducer shall be mounted on a rigid frame that is fixed to the test specimen at mid-height over the supports (see Figure 5). One end of the frame should be fixed to the specimen with a sliding fixture and the other end with a rotating fixture. Since the transducer should measure the deflection, a thin plate fixed at one end can be placed at mid-width across the notch mouth at the point of measurement (see Figure 5).

All bearing surfaces shall be wiped clean and any loose grit or other extraneous material from the surfaces of the test specimen that will be in contact with the rollers shall be removed.

The test specimen shall be placed in the testing machine, correctly centred and with the longitudinal axis of the specimen at right angles to the longitudinal axis of the upper and lower rollers.
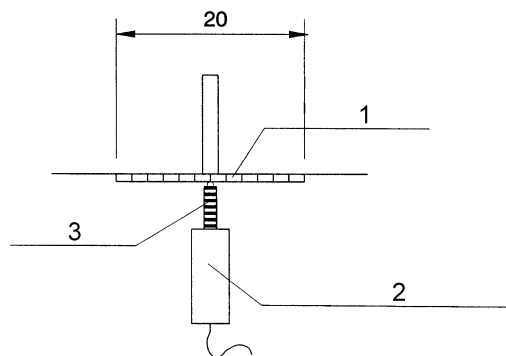
8.2   Bending test

Before the bending test, the average span length of the test specimen shall be determined from two measurements to the nearest mm of the axis distance between the supporting rollers on both sides of the specimen, using a ruler.

Dimensions in millimetres

section A-A
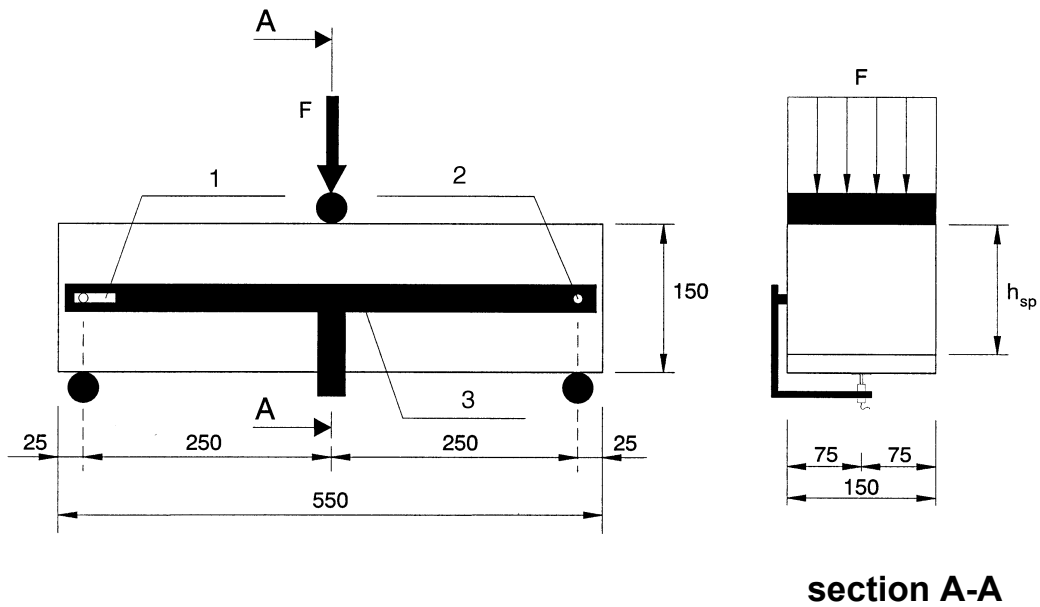
Key

1   Sliding fixture
2   Rotating fixture
3   Rigid frame

Key

1   1 mm thick aluminium plate
2   Transducer (linear variable differential transformer)
3   Spring shaft

Figure 5 — Typical arrangement for measuring deflection

The load shall not be applied until all loading and supporting rollers are resting evenly against the test specimen.

In case of a testing machine controlling the rate of increase of *CMOD*, the machine shall be operated so that *CMOD* increases at a constant rate of 0,05 mm/min. When *CMOD* = 0,1 mm, the machine shall be operated so that *CMOD* increases at a constant rate of 0,2 mm/min.

During the first two minutes of the test, the values of the load and corresponding *CMOD* shall be recorded at a rate not less than 5 Hz, afterwards this rate may be reduced to not less than 1 Hz.

The test shall be terminated at a *CMOD* value not less than 4 mm.

In case the minimum load value in the range $CMOD_{F_L}$ to *CMOD* = 0,5 mm is less than 30 % of the load value corresponding to *CMOD* = 0,5 mm, the testing procedure shall be checked for instability.

In case of a testing machine controlling the rate of increase of deflection, the above testing procedure shall be applied provided that the *CMOD* related parameters are transformed into deflection related parameters (see 9.1).

Tests during which the crack starts outside the notch shall be rejected.

9   Expression of results

9.1   Equivalence between CMOD and deflection

The relation between *CMOD* and deflection may be approximated by:

$$\delta = 0,85\ CMOD + 0,04 \tag{1}$$

where

δ is the deflection, in millimetres;

CMOD   is the *CMOD* value, in millimetres, measured in case the distance between the bottom of the test specimen and the line of measurement $y = 0$.

In case the line of measurement is at a distance y below the bottom of the specimen, the value of *CMOD* shall be derived from the measured value $CMOD_y$ using the expression:

$$CMOD = CMOD_y \cdot \frac{h}{h + y} \tag{2}$$

with

h the total depth of the specimen.

To transform the load-*CMOD* diagrams of the following Figures 6 and 7 into load-deflection diagrams, a transformation of the *CMOD* axis should be carried out using the *CMOD* and δ values of Table 1.

Table 1 – Relationship between *CMOD* and δ

CMOD (mm)	δ (mm)
0,05	0,08
0,1	0,13
0,2	0,21
0,5	0,47
1,5	1,32
2,5	2,17
3,5	3,02
4,0	3,44

9.2 Limit of proportionality

The *LOP* is given by the expression (see Annex A):

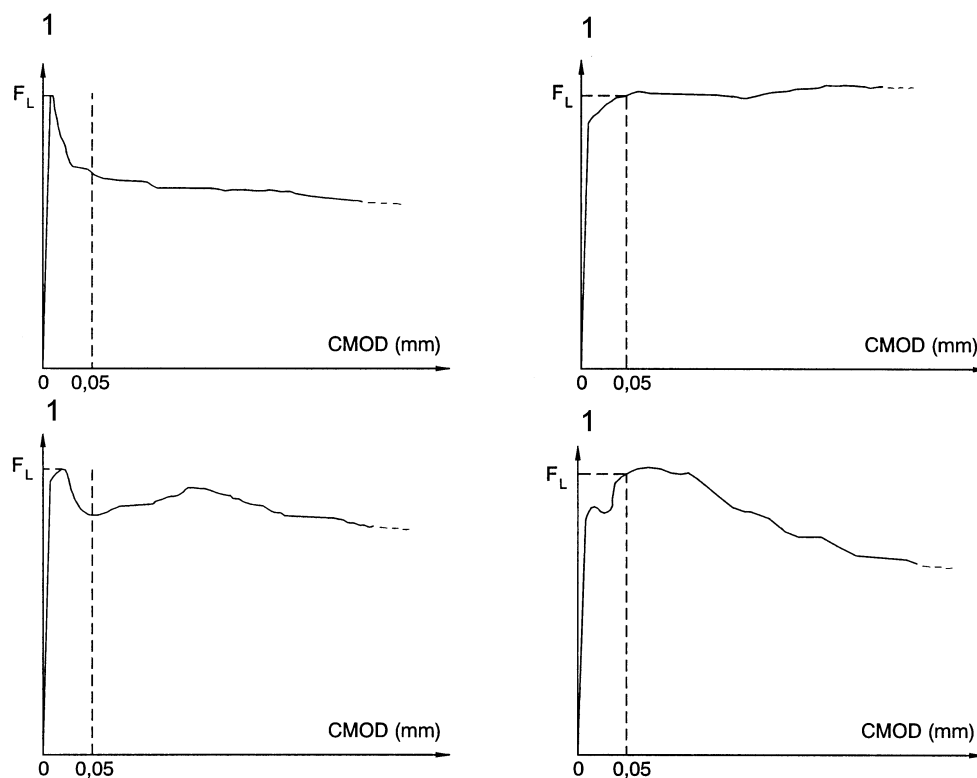$$f_{ct,L}^{f} = \frac{3 F_L l}{2 b h_{sp}^2} \tag{3}$$

where

$f_{ct,L}^{f}$ is the *LOP*, in Newton per square millimetre;

F_L is the load corresponding to the *LOP*, in Newton (see Figure 6);

l is the span length, in millimetres;

b is the width of the specimen, in millimetres;

h_{sp} is the distance between the tip of the notch and the top of the specimen, in millimetres.

Key

1   Load F

Figure 6 — Load-*CMOD* diagrams and F_L

The load value F_L shall be determined by drawing a line at a distance of 0,05 mm and parallel to the load axis of the load-*CMOD* or load-deflection diagram and taking as F_L the highest load value in the interval of 0,05 mm (see Figure 6).

The *LOP* shall be expressed to the nearest 0,1 N/mm^2.

9.3   Residual flexural tensile strength

The residual flexural tensile strength $f_{\text{R,j}}$ is given by the expression (see Annex A):

$$f_{R,j} = \frac{3F_j l}{2bh_{sp}^2}$$ (4)

where

$f_{\text{R,j}}$ is the residual flexural tensile strength corresponding with $CMOD = CMOD_\text{j}$ or $\delta = \delta_\text{j}$ (j = 1,2,3,4), in Newton per square millimetre;

F_j is the load corresponding with $CMOD = CMOD_\text{j}$ or $\delta = \delta_\text{j}$ (j = 1,2,3,4), in Newton (see Figure 7);

l is the span length, in millimetres;

b is the width of the specimen, in millimetres;

h_{sp} is the distance between the tip of the notch and the top of the specimen, in millimetres.
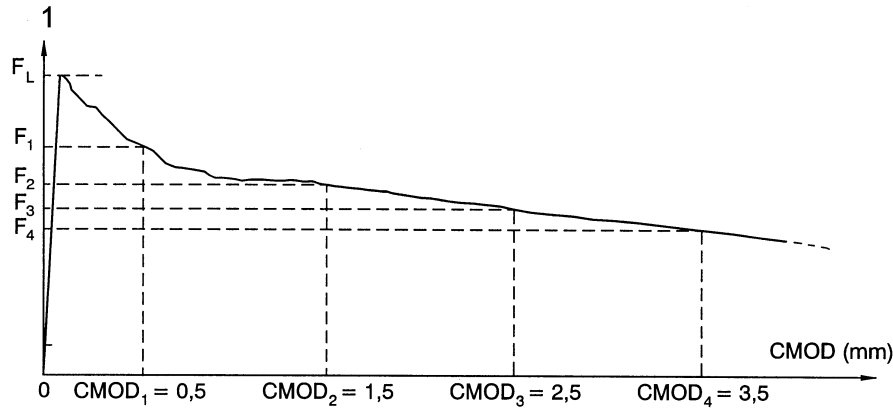
Key

1   Load F

Figure 7 – Load-*CMOD* diagram and F_j (*j* = 1, 2, 3, 4)

The residual flexural tensile strength shall be expressed to the nearest 0,1 N/mm^2.

10 Test report

The test report shall include:

a)   identification of the test specimen;

b)   identification of the concrete composition;

c)   date of manufacture;

d)   date of notching;

e)   date of testing;

f)   number of specimens tested;

g)   curing history and moisture condition of specimen at test;

h)   average width of specimen to the nearest 0,1 mm;

I)   average distance between the tip of the notch and the top of the specimen to the nearest 0,1 mm;

j)   dimensions x and *y*, in mm (see Figure 4);

k)   span length to the nearest mm;

l) rate of increase of *CMOD* or deflection and any deviation thereof;

m) load-*CMOD* curve or load-deflection curve;

n) *LOP* to the nearest 0,1 N/mm^2;

o) residual flexural tensile strength values corresponding to $CMOD_j$ or δ_j (*j* = 1,2,3,4) to the nearest 0,1 N/mm^2;

p) reference to this European Standard;

q) any deviation from the standard testing method;

r) optionally, observation of uniformity of fibre distribution at the fracture surface;

s) declaration from the person technically responsible for the test that the testing was carried out in accordance with this standard, except for the indicated deviation(s).

11 Precision

There is currently no precision data for this test.

Annex A
(informative)

Expressions for limit of proportionality and for residual flexural tensile strength
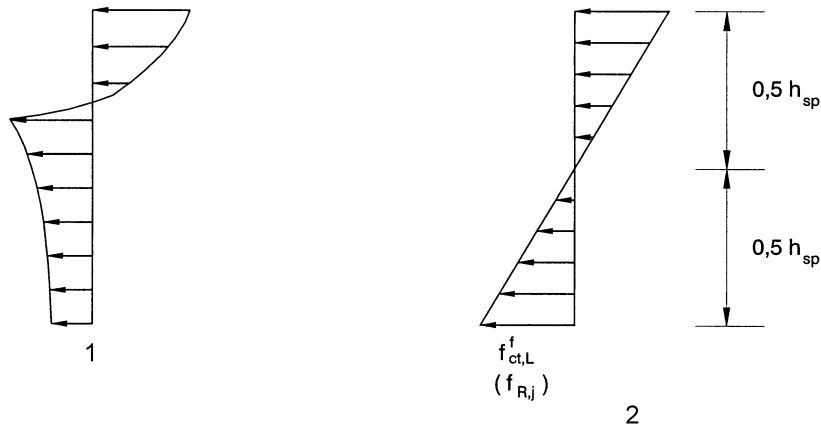
The bending moment at mid-span of the test specimen corresponding to the centre-point load F is (see Figure 1):

$$M = \frac{F}{2} \cdot \frac{1}{2} \qquad (5)$$

where

l is the span length.

Assuming a linear stress distribution as shown in Figure A.1,

Key

1   Real stress distribution

2   Assumed stress distribution

Figure A.1 — Stress distributions

the *LOP* $f_{ct,L}^{f}$ is given by the expression:

$$f_{ct,L}^{f} = \frac{6M_L}{bh_{sp}^2} = \frac{3F_L l}{2bh_{sp}^2} \qquad (6)$$

and the residual flexural tensile strength $f_{R,j}$ (j = 1,2,3,4) by the expression:

$$f_{R,j} = \frac{6M_j}{bh_{sp}^2} = \frac{3F_j l}{2bh_{sp}^2} \qquad (7)$$

where

F_L is the load corresponding to the LOP;

F_j is the load corresponding to $CMOD_j$ or δ_j (j = 1,2,3,4);

M_L is the bending moment corresponding to the load at LOP;

M_J is the bending moment corresponding to the load F_j (j = 1,2,3,4);

b is the width of the specimen;

h_{sp} is the distance between the tip of the notch and the top of the specimen in the mid-span section.